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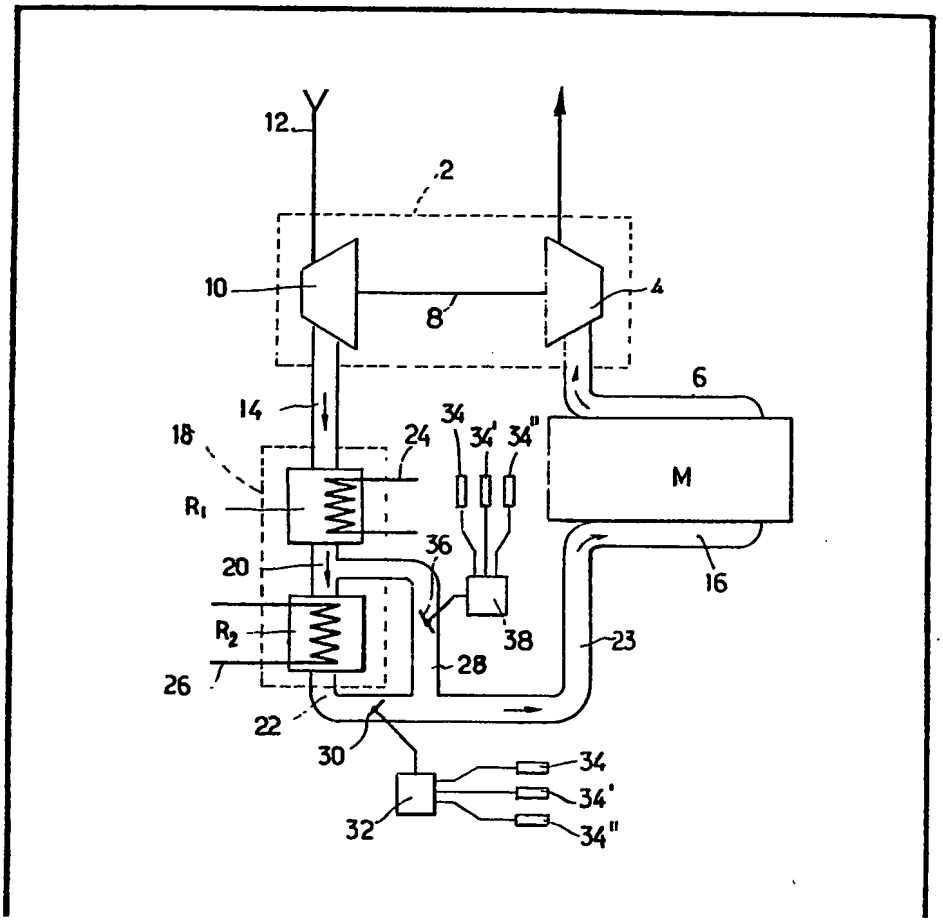
(54) Supercharging Internal Combustion Engines

(57) Supercharging air from a compressor 10 passes into a first, higher temperature, heat exchanger R1 and then into a second, lower temperature, heat exchanger R2. A bypass duct 28 permits a controllable proportion of the supply of supercharging air to bypass the second heat exchanger. One or more shutters 30, 36 control the proportion of air passing through the bypass, whereby the temperature of the supercharging air supplied to the engine M is controlled, for example in response to engine load, ambient temperature, supercharging air pressure and engine temperature.



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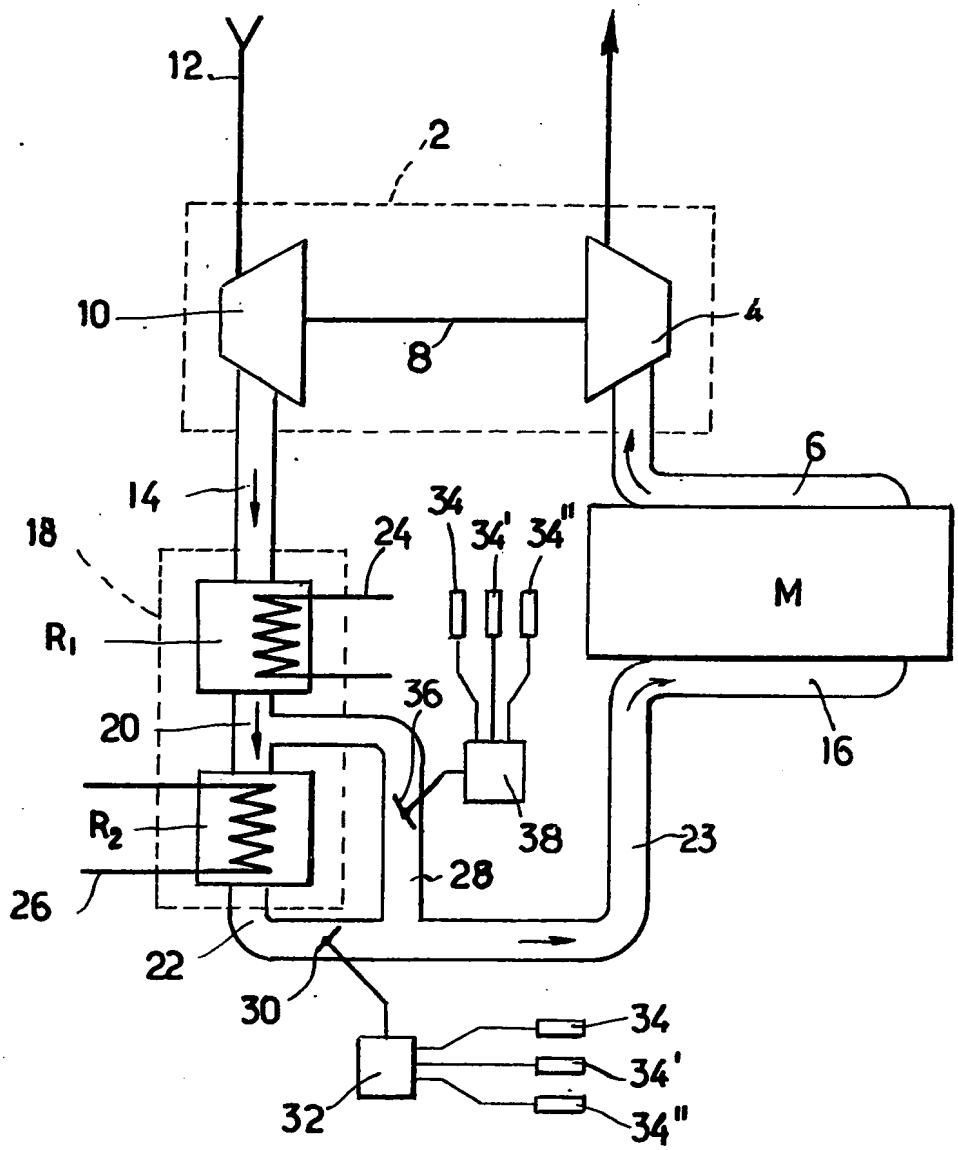
12
2
10
8
4
6
14
18
24
34
34'
34"
M
R1
36
20
16
R2
38
23
28
26
22
30
34
34'
32
34"

SPECIFICATION

Supercharging Apparatus

The present invention relates to supercharging apparatus comprising a compressor, for internal combustion engines such as diesel engines, and aims to provide means for controlling the temperature of the supercharging air supplied to the engine by the compressor.

It is known that, in a supercharged diesel engine, it would be convenient if the temperature of the air supplied by the compressor varied little whatever the operating conditions, so as to obtain satisfactory control of ignition timing and good combustion. This is why, so as not to obtain excessive temperatures when operating at full capacity, when the temperature of the air at the outlet of the compressor is high, it has been proposed to mount a heat exchanging system in the supercharging air circuit, between the oulet of the compressor and the air inlet of the engine.

Such a heat exchange system may comprise two heat exchangers. In certain engines, these two heat exchangers are mounted in parallel. In other engines, the two heat exchangers are mounted in series, the second heat exchanger being connected to a supply of heat exchange fluid (for example water from an exterior source, or ambient air) colder than the heat exchange fluid passing through the first heat exchanger. The first heat exchanger may be provided, as the heat exchanging fluid, with the liquid circulating in the cooling system of the engine itself.

The present invention relates particulary, but not exclusively, to systems of this second type, that is to say those having two heat exchangers in series, the first heat exchanger being a relatively high temperature heat exchanger, and the second heat exchanger being a relatively low temperature heat exchanger.

Previously proposed systems of this type go some way towards avoiding the supply to the engine when operating at full capacity, of supercharging air at a temperature which is too high. However, it is found that high ambient temperatures can nevertheless lead to excessive heat supply, whereas low ambient temperatures can lead to incomplete combustion causing soiling in the case of engines of normal compression ratio, or preventing operation in the case of engines of reduced compression ratio.

It has been proposed, in order to control the temperature of the air, to control the delivery or the temperature of the heat carrying fluids in the two heat exchangers, so that the system can operate to cool or to heat the supercharging air, according to the load, but this causes poor utilization of the heat exchangers, complication of the apparatus, and, in consequence, less reliability of operation.

Moreover, the control of the supply of heat carrying fluid entails a significant hysteresis factor, which can be a disadvantage when the

An object of the present invention is to provide supercharging apparatus for an internal combustion engine, the apparatus providing improved control of the temperature of the supercharging air supplied to the engine.

According to the invention there is provided supercharging apparatus for an internal combustion engine, the apparatus comprising:

a compressor;

a first heat exchanger arranged to receive heat exchange fluid at a first temperature;

a second heat exchanger arranged to receive heat exchange fluid at a second temperature which is lower than the first temperature;

the first and second heat exchangers being connected to the compressor in series with each other so that the supercharging air passes from the compressor successively through the first and second heat exchangers on its way to the engine;

characterized by a bypass duct to permit supercharging air to bypass the second heat exchanger.

Preferably control means is provided to control the proportion of the supercharging air passing through the bypass duct. The control means may comprise a shutter associated with the bypass duct or with the second heat exchanger, a servomechanism being provided to actuate the shutter. The servomechanism may be controlled by a sensor responsive to the pressure of the supercharging air, and/or responsive to at least one of the following parameters: ambient temperature, engine temperature, engine load, engine speed.

Said first temperature is preferably above maximum ambient temperature and is lower than the temperature of the supercharging air discharged by the compressor when the engine is operating under full load.

The invention also provides a method of operating a supercharged internal combustion engine comprising passing the supercharging air from a compressor to the engine through ducts including a heat exchanger and a bypass therefor.

The invention is applicable to diesel engines of normal compression ratio, but is more particularly applicable to engines of reduced compression ratio, that is to say, engines having a compression ratio of less than about twelve to one.

An embodiment of the invention will now be described by way of example with reference to the accompanying drawing which shows a diagrammatic representation of a diesel engine and supercharging apparatus therefor.

A diesel engine M is provided with supercharging apparatus comprising a turbocharger 2 having at least one turbine 4 which is driven by the exhaust gas from the exhaust manifold 6 of the engine and which is connected by a shaft 8 to a compressor 10. Generally, the supercharging apparatus is of two stages, but only one stage has been shown in order to simplify the drawing.

air to the engine M through its outlet duct 14. The outlet duct 14 is connected to the inlet manifold 16 of the engine M through temperature control apparatus 18 for the supercharging air.

The temperature control apparatus 18 comprises two heat exchangers R1 and R2 which are connected in series with each other and with the inlet manifold 16 of the engine M, by means of ducts 20, 22 and 23.

The first heat exchanger R1 has a circuit 24 in which circulates a heat exchange fluid which is relatively hot. For example, the circuit 24 can be supplied with the high temperature liquid from the liquid cooling system (not shown) of engine M.

The second heat exchanger R2 has a circuit 26 in which a heat exchange fluid circulates, which is cooler than that of the first heat exchanger. For example this fluid may be ambient air. If the engine M is a marine diesel engine, the circuit 26 of the second heat exchanger can have running through it sea water. In the case of a stationary engine, the circuit 26 could be connected to the local water supply.

In accordance with the invention, a bypass duct 28 for the supercharging air is provided for the second heat exchanger R2. The inlet of the bypass duct 28 is connected to duct 20, between heat exchangers R1 and R2, and the outlet of duct 28 is connected to duct 22 on the downstream side of heat exchanger 22, that is to say between the outlet of R2 and the inlet manifold 16 of engine M.

Control means for the flow of supercharging air, in the form of a shutter 30, is mounted in duct 22 and is controlled by a servomechanism 32 actuated by one or more sensors 34, 34', 34" which sense the operating parameters of engine M, such as the supercharging air pressure, the ambient temperature, and the temperature of or the load on the engine itself.

For certain applications, it is advantageous to provide control means for the flow of supercharging air in the form of a shutter 36 in the bypass duct 28, this shutter being controllable by a servomechanism 38 connected to the sensors 34, 34' and 34".

The operation of the supercharging apparatus under various conditions of operation of the engine, will now be described.

It must first be noted that the high temperature heat exchanger R1 which has passing through it the cooling liquid of engine M (at 80° Celsius to 100° Celsius) operates to heat the supercharging air under low and medium load conditions, and operates to cool the supercharging air when, with increasing loads, the temperature of the compressed air discharged by compressor 10 is equal to the temperature of the heat exchange fluid passing through the high temperature heat exchanger R1.

In the absence of the shutters 30 and 36 in ducts 22 and 28, the distribution of the supercharging air between these ducts is a exchange element of heat exchanger R1 causes bypass duct 28 to have a lower flow resistance than that of heat exchanger R1. If bypass duct 28 is of low resistance (large diameter) the flow through it attained will be three quarters and even more of the total air flow, so that at low or medium loads the heating effect of the two heat exchangers will be significant, though not reaching the heating effect obtained when all the air passes through the bypass duct.

If a shutter is provided only in the low resistance bypass duct (shutter 36) the heating effect will not be a maximum with the shutter open since some air will nevertheless pass through R2, but the cooling effect will be maximum when, at full load, the shutter is closed. This arrangement is particularly suitable for engines of normal compression ratio, for which it is desirable to obtain a certain level of heating of the supercharging air at partial loads, but maximum cooling of said air at high loads.

If the bypass duct 28 is of relatively high resistance (small diameter), the proportion of the total air flow through it will be reduced (20% for example) and, with the ducts 22 and 28 completely open, the resulting supercharging air temperature will approach the minimum air temperature achieved with the total air flow passing through the two heat exchangers in series.

With the shutter 30 mounted downstream of the low temperature heat exchanger R2, when this shutter is closed and the engine is under zero or low load conditions, maximum heating of the supercharging air is achieved. This arrangement is generally more suitable for engines of reduced compression ratio for which it is desirable to provide maximum heating under zero and low load conditions.

If, on the other hand, one wants, for high load conditions, to make use of the total cooling capacity of heat exchangers R1 and R2, it is desirable to provide the second shutter 26 in bypass duct 28 so that with shutter 36 closed and the shutter 30 open the total supercharging air flow passes through the two exchangers R1 and R2 in series.

It must be remembered that the temperature of the supercharging air at the outlet of compressor 10 depends, for a given ambient air temperature, only on the compression provided by the compressor. It follows that the control of the shutters 30 and 36 is preferably related directly or indirectly to the compression so provided, such as by means of a sensor 34 controlling servomechanism 32 and 38.

The degree of opening of each of the two shutters is related to the degree of opening of the other shutter.

In the case of the shutter 36 in bypass duct 28 the shutter is completely open when starting up and when running under zero or low load conditions. From a supercharging air pressure which depends on the air temperatures which it is

(integrated with the influence of the ambient air temperature), the shutter will be progressively closed, so as to be completely closed under conditions between half load and three quarters load. However, when the engine has to operate at very low ambient temperatures, a correction will be applied such that the shutter will not be completely closed even under maximum loads, so as to avoid the disadvantages arising from the supply to inlet manifold 16 of air at too low temperatures.

In the case of shutter 30 installed downstream of the low temperature exchanger R2, this shutter 30 is completely closed on starting and under zero and low load conditions. From a certain pressure of the supercharging air, the shutter progressively opens so as to be fully open for a load condition between half load and three quarters load.

As in the case of shutter 36, the effect of ambient temperature is to cause partial closing of shutter 30 at full load when the engine is operating in very low temperature conditions.

It should be noted that in this apparatus, and in contrast to the full load conditions discussed above, the degree of heating of the supercharging air provided under zero or low load conditions is practically independent of the ambient temperature. The temperature of heat exchanger R1 is practically constant since it is controlled by the cooling fluid of engine M, and the mass of supercharging air to be heated is relatively small with respect to the thermal capacity of the heat exchanger R1.

The third situation, where the two shutters 30 and 36 are both provided, constitutes only a development of the preceding example. When, in the region of half load for example, the shutter 30 reaches its fully open position, the shutter 36 of the bypass commences to close in order to reach complete closure between three quarters and full load, for example.

Of course, in the case where the two shutters 30 and 36 are both used, these two shutters can be replaced by a three-way air valve dividing the flow of supercharging air between the exchanger R2 and the bypass duct 28, and situated, for example, between the two exchangers in duct 20.

It will be understood from the foregoing that the above embodiment of the invention provides means for attaining satisfactory control of the temperature of the supercharging air supplied to the inlet manifold of internal combustion engines such as classical diesel engines and in particular diesel engines of reduced compression ratio, with good utilization of the capacity of the heat exchangers.

With this new arrangement, the high temperature heat exchanger operates as a cooling means under high load conditions and can, in the case of very high supercharging, remove more than half the heat which it is desirable to remove, the low temperature exchanger having to remove dimensions.

An important advantage provided by the invention is the rapid response rate for temperature control, in the case of rapid variation of the load on the engine.

By way of example, the operation of an engine of low compression ratio will be considered, for which the inlet air temperature should be of the order of 70° Celsius and of which the turbocharger under full load works with a compression ratio of 4.

At the outlet of the compressor, temperatures around ambient temperature, for example 25° Celsius, are obtained at low load conditions, and temperatures around 220° Celsius at full load. This temperature, for a given ambient temperature, depends only on the compression provided by the compressor and is established almost without delay according to the pressure level. Since an engine is able to change from full load to zero load in a fraction of a second, it is clear that control means proposed up to now which operate by controlling the flow or the temperature of the heat exchange fluid are incapable of maintaining at all times an inlet air temperature around 70° Celsius having regard to the hysteresis of the apparatus.

On the other hand, supercharging apparatus according to the invention acts upon the flow of air itself as it passes through the heat exchangers and, depending on the desired form of the apparatus, the position of the shutter or shutters is directly related to the pressure of the supercharging air, whereby a very rapid response rate is achieved assuring satisfactory temperature control despite rapid variations in load.

In the case where the control of the shutter or shutters is in accordance with an operational parameter of the engine, these parameters are only applied as control factors to modify the position of the shutters whereby delays in response are avoided, the basic position of the shutter being determined by the pressure of the supercharging air.

The invention is not limited to the embodiments described and represented, it is susceptible of numerous variations apparent to the man skilled in the art without departing from its underlying scope.

Claims

1. Supercharging apparatus for an internal combustion engine, the apparatus comprising:

a compressor;

a first heat exchanger arranged to receive heat exchange fluid at a first temperature;

a second heat exchanger arranged to receive heat exchange fluid at a second temperature which is lower than the first temperature;

the first and second heat exchangers being connected to the compressor in series with each other so that the supercharging air passes from the compressor successively through the first and

supercharging air to bypass the second heat exchanger.

2. The apparatus of claim 1 characterized by flow control means to control the proportion of the supercharging air passing through the bypass duct.

3. The apparatus of claim 1 characterized in that said first temperature is above maximum ambient temperature and is lower than the temperature of the supercharging air discharged by the compressor when the engine is operating under full load.

4. The apparatus of claim 3 characterized in that said first heat exchanger is connected to the cooling system of the engine to receive heat exchange fluid therefrom.

5. The apparatus of claim 1 characterized in that said second heat exchanger is adapted to exchange heat between the supercharging air and ambient air.

6. The apparatus of claim 1 characterized in that the second heat exchanger is adapted to exchange heat between the supercharging air and cold water from a source outside the engine.

7. The apparatus of claim 2 characterized in that said flow control means comprises a shutter associated with the bypass or the second heat exchanger, and a servomechanism is provided to actuate the shutter.

8. The apparatus of claim 7 characterized in that said servomechanism is controlled by a sensor responsive to the pressure of the supercharging air.

9. The apparatus of claim 8 characterized in that said servomechanism is controlled by a sensor responsive to at least one of the following parameters: ambient temperature, engine temperature, engine load, engine speed.

10. The apparatus of claim 2 characterized in that said flow control means comprises an air valve to divide the supercharging air between the bypass and the second heat exchanger.

11. Supercharging apparatus for an internal combustion engine substantially as described herein with reference to the accompanying drawing.

12. An internal combustion engine having apparatus according to any preceding claim.

13. An engine according to claim 12 characterized in that the engine is a diesel engine and said compressor is driven by a turbine operated by the exhaust gas of the engine.

14. A method of operating a supercharged internal combustion engine comprising passing the supercharging air from a compressor to the engine through ducts including a heat exchanger and a bypass therefor.

15. The method of claim 14 including the step of controlling the temperature of the supercharging air supplied to the engine by varying the proportion of said air which passes through the bypass.

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ABSTRACT:
CHG DATE=19990617 STATUS=O> Supercharging air from a compressor 10 passes into a first, higher temperature, heat exchanger R1 and then into a second, lower

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exchanger. One or more shutters 30, 36 control the proportion of air passing
through the bypass, whereby the temperature of the supercharging air supplied
to the engine M is controlled, for example in response to engine load, ambient
temperature, supercharging air pressure and engine temperature. <IMAGE>